



Nordic Council
of Ministers

AIR QUALITY FOR ALL

**A Nordic air quality web-conference
10–11th of June 2020**

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This publication is also available online in a web-accessible version at <https://pub.norden.org/temanord2022-508>.

Summary

A group of Nordic air quality researchers organised 10–11th of June 2020 a web-conference on Nordic air quality research for civil servants and the general audience. The name of the conference was *Air Quality for All - A Nordic air quality conference* (AQ4ALL), and it included an overview of research from three air quality research programmes with active Nordic participation. Presentations were made by researchers from the Swedish Clean Air and Climate (SCAC) research programme (duration 2013–2020), the Nordic-WelfAir (NWA, 2015-ongoing) research project, as well as the EU-funded project Action on Black Carbon in the Arctic (EUA-BCA, 2018–2021).

The aim of the SCAC Programme was to develop and improve the scientific basis for air pollution policies on national and international scales including relations to climate policy. The purpose of Nordic-WelfAir is to increase our understanding of links between air pollution levels, the chemical composition of the pollution and related health effects, as well as to investigate and assess which groups in society that are worst affected by air pollution and how the welfare system addresses such effects. Finally, the EU project Black Carbon in the Arctic contributed to black carbon emission policies in the Arctic by supporting the development of commitments and targets to limit production of Arctic black carbon and by enhancing international cooperation on black carbon policy in the Arctic region. Based on the projects, the themes of the conference included:

- *Air quality effects on the Nordic welfare system,*
- *Nordic air pollution and the Arctic climate – effects and solutions,*
- *Air pollution effects on public health and the environment*

The participants were also given the opportunity to learn more about how applied air quality research is done in practice under the fourth theme *Improved data, improved models, better decision support for policy.*

The key messages under the first theme are that the existence of air pollution inequality is unevenly spread over Europe, and the importance of local circumstances requires analysis to be made on a case-by-case basis. It is also important to better disseminate knowledge on air pollution effects on human health to decision makers in the welfare sector.

From the second theme, the main messages are that the most important source of air pollutants that warm the climate is combustion of fossil fuel, just as it is for greenhouse gas emissions. Furthermore, emissions from the Nordic countries have disproportionate large impact on Arctic Warming, and effective Nordic air pollution policies could slow down Arctic warming.

Under the third theme it was clarified that air pollution still has large human and environmental health effects in the Nordic region. New research has shown that no lower threshold has been found for when air pollution is harmless. The damages from ground-level ozone are changing nature rather than being solved, and nitrogen deposition over Nordic ecosystems is still too high.

Due to the COVID-19 pandemic, the organisation of the conference shifted from a

mixed real-life & virtual conference into a 100% web-conference. The conference attracted more than 200 visitors from 18 countries, including countries in Asia and North America. The maximum number of participants at any given occasion was 171 persons.

On the conference website (<https://www.ivl.se/aq4all>), all recorded presentations are available.

Sammanfattning

En grupp nordiska luftkvalitetsforskare organiserade den 10–11 juni 2020 en webbkonferens om nordisk luftkvalitetsforskning för såväl tjänstemän som allmänheten. Konferensen gick under namnet *Air Quality For All - A Nordic air quality Conference* (AQ4ALL), och den presenterade en översikt av forskning från tre luftkvalitetsforskningsprogram med aktivt nordiskt deltagande. Presentationer hölls av forskare från forskningsprogrammet Swedish Clean Air and Climate (SCAC) (varaktighet 2013–2020), forskningsprojektet Nordic-WelfAir (NWA, 2015-pågående), samt det EU-finansierade projektet Action on Black Carbon i Arktis (EUA-BCA, 2018–2021).

Syftet med SCAC var att utveckla och förbättra den vetenskapliga grunden för luftföroreningspolicy på nationell och internationell nivå, inklusive relationer till klimatpolicy. Syftet med Nordic-WelfAir är att öka vår förståelse för kopplingar mellan luftföroreningsnivåer, föroreningarnas kemiska sammansättning och relaterade hälsoeffekter, samt att undersöka vilka grupper i samhället som drabbas värst av luftföroreningar och hur välfärdssystemet hanterar detta. Slutligen bidrog EU -projektet EUA-BCA till utsläppspolicies i Arktis genom att stödja utvecklingen av åtaganden och mål för att begränsa sotpåverkan i Arktis, och genom att stärka det internationella samarbetet kring sot-policy i den arktiska regionen. Med bas i den kunskap som tagits fram i forskningsaktiviteterna var konferensens teman:

- *Luftkvalitetseffekter på det nordiska välfärdssystemet,*
- *Nordiska luftföroreningar och det arktiska klimatet - effekter och lösningar,*
- *Luftföroreningseffekter på folkhälsan och miljön.*

Deltagarna fick också möjlighet att lära sig mer om hur tillämpad luftkvalitetsforskning görs i praktiken under det fjärde temat *Förbättrad data, förbättrade modeller, bättre beslutsstöd för policy.*

De viktigaste budskapen under det första temat är att förekomsten av ojämlikhet i luftkvalitet är ojämnt fördelad över Europa, och vikten av lokala omständigheter kräver att analyser görs från fall till fall för att åtgärda ojämlikhet. Det är också viktigt att bättre sprida kunskap om luft-föroreningars effekter till beslutsfattare inom välfärdssektorn.

Från det andra temat är huvudbudskapen att den viktigaste källan till klimatuppvärmande luftföroreningar är förbränning av fossila bränslen, precis som det är för utsläpp av växthusgaser. Dessutom har utsläppen från de nordiska länderna oproportionerligt stor inverkan på uppvärmning av Arktis. En effektiv nordisk luftföroreningspolitik kan bromsa uppvärmningen.

Under det tredje temat klargjordes att luftföroreningar fortfarande har stora hälsoeffekter för människor och miljö i Norden. Ny forskning har visat att man inte hittat någon lägre tröskel för när luftföroreningar är ofarliga. Skadorna från marknära ozon förändras snarare än löses, och kvävedepositionen över nordiska ekosystem är fortfarande för hög.

På grund av COVID-19-pandemin övergick organisationen av konferensen från en blandad fysisk och virtuell konferens till en 100% webbkonferens. Konferensen lockade

mer än 200 besökare från 18 länder, inklusive länder i Asien och Nordamerika. Det maximala antalet deltagare vid ett och samma tillfälle var 171 personer. På konferensens webbplats (<https://www.ivl.se/aq4all>) finns alla presentationer och inspelade videor tillgängliga.

Why the AQ4ALL conference?

The background of the AQ4ALL project is the identification of a unique opportunity of co-ordinating final conferences of the SCAC and NWA programmes with the outreach activities of the EUA-BCA. Thereby, the two largest Nordic air quality research programmes has an unforeseen opportunity to reach out with the latest knowledge produced within the programmes. Further, through the interaction with the EUA-BCA, the research questions can also be aligned with, and put in perspective of, the EU research agenda to initiate activities to curb arctic climate change through reduced emissions of black carbon, a problem to which the Nordic countries have substantial contribution.

A joint project result dissemination is of high environmental political relevance for the Nordic countries since the research results directly relates to the Swedish Environmental Quality Objectives: Zero Eutrophication, Only Natural Acidification, Clean Air, Limited Global Warming, and the corresponding targets in the other Nordic countries.

This project would not have been contemplated if it wasn't for previous past positive experience of the participating organisations: both the direct applicants as well as the partner organisations within the research programmes. The researchers within SCAC have by now collaborated for some 13 years in applied air quality research, the partners in NWA have collaborated within the programme for five years but in many cases also for much longer. As examples, IVL Swedish Environmental Institute (IVL) (partner in all three research activities) has collaborated with the Finnish Environment Institute (SYKE) in Finland (partner in two of the activities) since at least 2007. Further, the partners in EUA-BCA have collaborated in several other ways: the Arctic Monitoring and Assessment Programme (AMAP) (EUA-BCA partner) and IVL have collaborated in several assessments and research projects on mercury and POPs in the Arctic, SYKE and the International Institute for Applied Systems Analysis (IIASA) (EUA-BCA) have together done much modelling research on black carbon, and IVL and IIASA are working actively together in integrated assessment modelling since 2013. At least 20 co-publications between the institutes and research organisations have been produced over the years. In short, the previous successful collaboration between the partners vouches for a successful project implementation.

The Swedish Clean Air and Climate Research Programme

The Swedish Clean Air and Climate Research Programme (SCAC) programme (2013–2020) was initiated to provide an extended scientific knowledge-base in national and international discussions and negotiations on the development of new air pollution policies and measures. The research focused on five main areas: Air pollution and climate interactions, Human health impacts from air pollution, Ecosystem effects of air pollution (including ground-level ozone and nitrogen pollution), and Integrated climate and air quality assessment of emission control. An emphasis was on the interlinkages between air pollution and climate change. One

such area of research was how air pollution emissions are influencing the climate at Northern altitudes. Modelling using an advanced Earth System Model and emission scenarios for sulphur and black carbon has shown that reduced emissions of sulphur at mid-latitudes cause increased temperatures and heat transport in the atmosphere and an increased warming of the Arctic. Reduced emissions of black carbon lead instead to reduced heat transport and a cooling effect. In terms of climate impact per unit mass, emission reductions of soot (reduced warming) result in a 3–5 times larger Arctic temperature change compared to sulphur (reduced cooling) (13–15).

Interesting examples from the studies of human health impacts were the studies of health aspects from local and disperse sources, such as small-scale residential wood combustion (RWC). Studies were directed to three cities in Sweden. In the studies, a comprehensive air quality model was developed which allowed for estimation of concentrations and exposures in spatial scales ranging from regional down to street level resolution, including source appointments of the exposure estimates. These exposure effect studies indicated health effects well below present air quality guidelines (16).

Another link between air pollution and climate change was how ozone exposure might influence the uptake of carbon in forest ecosystems and in this way counteract the role of forests in binding carbon dioxide. The initial studies made in SCAC could not confirm such an effect, but the evaluation showed that this non-result can be suspected to be due the data sets not being large enough (17). In addition, SCAC researchers adapted the method proposed to national nitrogen budgets to Swedish conditions and calculated such a budget with less than 1% difference in in/out balance of the nitrogen flows.

SCAC results also show that efficiency improvements, use of non-combustion energy sources and behavioural changes all ensure co-benefits between climate change and air pollution although some risks for trade-offs can be identified. Primarily, the use of solid biofuels for electricity and heating can decrease CO₂ emissions but is at risk of increasing emissions of some air pollutants.

Further information is given on the SCAC web page: <https://www.scac.se/>

The Nordic-WelfAir project

The project: Understanding the link between Air pollution and Distribution of related Health Impacts and Welfare in the Nordic countries – Nordic-WelfAir – is funded through NordForsk's Nordic Programme on Health and Welfare (2015–2022). It is a large project including 16 partners from Denmark, Finland, Iceland, Norway and Sweden. It is a highly interdisciplinary project, ranging over scientific fields of emission inventories, atmospheric modelling, epidemiological and health research, health impact assessment and related external costs as well as welfare research. The aim of the project is to improve each step from emission calculations to exposure estimates, by taking advantage of the unique high-resolution databases and registers in the Nordic countries. Thereby the researchers in the project strives to understand what kind of air pollution, with respect to chemical composition and sources, that causes the impacts on human health for different target/population groups and assessing the effects on the well-being and welfare. Furthermore, new

knowledge on the challenges this will have for the Nordic welfare systems is expected resulting in development of policy options proposing solutions to the public health and welfare challenges.

The setup of the first all-Nordic emission inventory on a common high resolution 1 km x 1 km Nordic map, is a main output of the project. Emission experts from all five Nordic countries have compared and harmonized methods in order to setup the new improved inventory. For several countries (e.g. Iceland), this has led to the development of the first high-resolution emission inventory based on local proxies.

Furthermore, RWC is an example of an important source for air pollution in many regions of the world. This is true also in the Nordic region, where RWC is widely used for heating and for "cosy-ness". In Nordic-WelfAir the research related to RWC has applied detailed national information on various spatial proxies (e.g. building and dwelling registers) and wood use data, to create a new and harmonized emission inventory for RWC. A new paper describes how these local characteristics of residential wood combustion improves the spatial distribution of emissions compared to standard inventories applied for Europe (18). The RWC-focused research has also analysed and compared the influence of RWC on the air pollution levels in four Nordic cities (19) and assessed the health impact related to RWC emissions in the same cities. This shows that RWC is one of the largest sources of PM_{2.5} in the Nordic cities and can be associated with about 4,000 years of life lost per year in total in these four cities. This pinpoints that further public health measures are needed in the Nordic in order to reduce the impacts from this important source for air pollution.

A common Nordic air pollution modelling framework have been setup, where Nordic models from hemispheric scales, continental scale, national scale and urban scale are coupled to form an integrated system, capable of calculating air pollution levels at very high geographical resolution (down to 1 km x 1 km) for all the Nordic countries. The model simulations cover a 40-year period. This has been used in a health assessment comparing different assessment tools (20). The number of premature deaths attributable to PM_{2.5} exposure ranged 8500 to 11,400 per year in the Nordic region (2015 data), illustrating the importance of air pollution also in a low concentration area as the Nordic, but also the uncertainties related to the current applied tools.

Finally, several health studies have been published and more are on the way with the focus on a number of health outcomes. This includes e.g. a study in Stockholm where the new Nordic model data was applied in combination with register data covering the period 2006–2013 (21). It was concluded that small children exposed to air pollution may have an increased risk for developing childhood asthma. It also includes the first nationwide study of the link between long-term exposure to air pollution and mortality. Again, the 1 km x 1 km model data was combined with register data, in this case the nation-wide Danish Registry of Causes of Death (22). The study showed that higher concentrations of PM_{2.5}, BC, and NO₂ at the home address were correlated with higher natural cause, respiratory, and lung cancer mortality.

Further information is given on the Nordic-WelfAir web page <https://projects.au.dk/nordicwelfair/>

The EU-funded Action on Black Carbon in the Arctic

The Arctic is a strategically important region and is experiencing dramatic, transformative impacts from climate change. It is important to take urgent action on emissions of black carbon to reduce its warming effect on the Arctic, improve air quality, and protect human health. Cost-effective technologies to reduce black carbon emissions already exist and can be implemented now.

The EU-funded Action on Black Carbon in the Arctic (EUA-BCA), which runs 2018–2021, is meant to contribute to efforts to reduce black carbon emissions in the Arctic. There are two main aims of EUA-BCA. The project is to support the development of commitments and targets to limit production of Arctic black carbon, with a focus on the three regionally important human sources from Arctic nations (gas flaring from oil and gas fields, residential heating—including heating stoves and diesel fuel use—and maritime shipping). The project also strives to enhance international cooperation on black carbon policy in the Arctic region.

The action has four major work components:

- Improving the knowledge base on black carbon emissions,
- Increasing awareness and sharing knowledge,
- Preparing technical advice documents and scenario analyses, and
- Supporting development of a policy landscape for international cooperation on black carbon.

The Action is in regular contact with relevant international efforts addressing black carbon, including those under the UN Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution, the Climate and Clean Air Coalition, the Intergovernmental Panel on Climate Change, and the United Nations Framework Convention on Climate Change.

More information about the project, its results, and access to all publications can be found at <https://eua-bca.amap.no/>.

Objective and achievements of the conference

The objective of AQ4ALL was to disseminate both new research with air quality policy implications to a wide Nordic audience and to disseminate knowledge on the possibility for low-carbon footprint conferencing. The AQ4ALL conference answered directly to several of the Nordic Working Group on Climate and Air (NKL) aims, priorities and objectives (mainly NKL 2019 priority #3 and the 2020 priority #6 and #7). It directly related to strengthening the implementation of the SDGs in the Nordic countries and it disseminated information on Nordic air pollution effects. The intended audience of the web-conference was local decision makers/city planners, as well as national and international policy makers in the field of air pollution. The project was thereby relevant for the environmental administration and policies of the Nordic countries. More concretely, through synthesis and dissemination of new research the project helped increasing awareness of equity and other welfare effects of air pollution, as well as the interaction between local/national/regional air quality strategies and air pollution effects on Arctic warming.

200 persons from 16 countries participated at AQ4ALL. Most of the participants were from the Nordic air pollution research community, but national, county, and municipal authorities in the Nordic countries were also well represented, as well as non-governmental organisations and private companies. The conference was well received with much positive feedback to the organisers after the conference.

Take home messages

Divided into four themes, the conference presented the latest knowledge and ongoing research. The first theme focused on air quality effects on the Nordic welfare and welfare system and included presentations from Aarhus University, European Environment Agency, and SYKE. The second theme presented the latest results regarding how Nordic air pollution affects the Arctic climate. Here the audience listened to presentations from Stockholm University, the Center for International Climate Research in Oslo (CICERO), and IVL. The third theme included discussions on the latest knowledge related to air pollution effects on human health and the environment, with participation from experts at Aarhus University, the Norwegian Institute of Public Health, Umeå University, the Finnish National Institute for Health and Welfare, and the University of Iceland. Finally, the fourth theme dived deeper into the data, methods, and models used by researchers to provide reliable policy support to decision makers and the public at large. Presentations were given by SYKE, the Norwegian Institute for Air Research, Aarhus University, and Stockholm University. Hyperlinks to all videos are given in the text and all slide presentations are available on the website <https://www.ivl.se/aq4all>.

Air quality effects on the Nordic welfare system

Key messages

- Air quality inequality is unevenly spread over Europe.
- The importance of local circumstances requires analysis to be made on a case-by-case basis.
- Our knowledge on how air pollution affects our health, and thereby our welfare systems, should be better disseminated to decision makers in the welfare sector.

The conference started with a [presentation](#) by Camilla Geels from Aarhus University who presented the state-of-play of Nordic air quality research. Air quality have improved significantly in the Nordic throughout the last decades. There are, however, still many negative impacts related to air pollution. It has e.g. been estimated that between 8,500–11,400 people die prematurely due to exposure to PM_{2.5} in the Nordic area. Increased knowledge show that also health effects like asthma, and several cognitive deficits like e.g., ADHD can be related to exposure to air pollution. Air pollution is there by affecting also the quality of life for many people. For Denmark alone it has been estimated that the negative health impacts related to air pollution cost the Danish society about 85 billion DKK per year. The Nordic welfare would hence benefit both financially and in terms of human wellbeing if the air quality were improved in the Nordic area.

In an overview of research made under the auspices of the European Environment Agency, Alberto Gonzales-Ortiz and Aleksandra Kazmierczak [presented](#) the current knowledge frontier on air pollution inequality in Europe. One important message is that air quality inequality occurrence is irregular over Europe. Even though it is common to find regions and cities in with clear signals of air quality inequalities, no general patterns can be found. Air quality inequality must be estimated on a case-by-case basis. Over time, exposure to air pollution have reduced. And those in socially or poor situations (low socio-economic status ~ unemployed, with low incomes, or low levels of education) have generally benefited at least as much as those in the least deprived communities. But these groups have not benefitted more than other groups, so they still tend to be more negatively affected by air pollution, as a result of their both greater exposure and higher vulnerability.

That air pollution inequality is a local rather than a general problem in the Nordic region was also corroborated by [Anna Strandell](#) from the Finnish Environment Institute. Recent research from Nordic-WelfAir cannot confirm large-scale inequalities between municipalities, and neither are there any exposure differences between age groups and genders. These does not mean that air pollution inequality is a non-issue in the Nordic region, rather that this inequality exists within municipalities or in local clusters. It is still important to continue studies on urban-rural differences, effects of population changes, as well as high-resolution studies.

Anne Jensen from Aarhus University [presented](#) governance dimensions of welfare and air quality. Current research in Nordic-WelfAir is also studying if and in what way air quality policies and welfare policies are integrated. The preliminary results indicate that welfare and air quality is treated as separate issues by governing bodies. Furthermore, both welfare and air quality objectives appear to be crowded out by more technical and tangible objectives related to housing, social policy, transport etc. The research has identified that one feature impeding further integration of welfare and air quality is that knowledge on the integrative features of air pollution and welfare is fragmented and specialized. This can hamper effective communication between relevant decision makers or stakeholders.

Nordic air pollution and the Arctic climate – effects and solutions

Key messages

- Air pollutants as particles can both warm the climate and combustion of fossil fuel is the most important source of warming particles, just as it is for greenhouse gases,
- Emissions from the Nordic countries have disproportionate large impact on Arctic Warming, Nordic policies could make a real difference,
- The time lag between scientific observations and policy action must become shorter.

In the second session of the conference the focus was on air pollution and the Arctic. [HC Hansson](#) from Stockholm University and [Maria Sand](#) from CICERO presented the relationship between air pollution and climate change, in particular Arctic Warming. As a summary, air pollutants as particles can both warm and cool the climate. Combustion of fossil fuel is the most important source of such particles, as it is for emissions of greenhouse gases.

Short-lived climate forcer is the term used for air pollutants that contribute to (or mask) warming but have lifetimes in the atmosphere of a few days to a few decades - much shorter than the equivalent atmospheric perturbation time of carbon dioxide. The shorter the lifetime, the more quickly atmospheric concentrations can be reduced by lowering emissions to provide climate mitigation benefits in the short term. From the best available estimates, the overarching message is that the climate effect of particles takes multiple routes. One route is that particles in the atmosphere can absorb sunlight, which increases warming. Another route is that once a soot particle is deposited on snow or ice, it reduces the Arctic snow/ice ability to reflect incoming sunlight, which can cause increased warming and snow/ice melting. In addition, soot particles in the atmosphere outside the Arctic, even when not physically transported to the Arctic, can induce transfer of warm air to the Arctic, which then again induces warming. Particles also affects cloud formation, but whether this induces warming or cooling depends on when, where, and how high the clouds are formed. For all the above effects on Arctic warming it is also important at what time of the year that the emissions occur.

Annica Ekman from Stockholm University [presented](#) more detailed results from the SCAC programme and other research on the climate effects of actually reducing emissions. The lessons learned from the research are inter alia that the largest impact of regional changes in northern hemispheric particle emissions always occurs in the Arctic, an effect driven by atmospheric heat transport changes. If emissions changes occur at approximately the same latitude (north/south), the longitude (east/west) doesn't matter much for the climate effect. The most important cooling particle (sulphate particles) has per kg emission change smaller climate effect than the warming particle soot. It should thereby be possible to make an integrated

consideration of the climate effect of air pollutants. With an integrated consideration, air pollution policy makers can "climate compensate", and avoid any additional warming of the Arctic from air pollution control of cooling particles. As a final reminder from Annica, HC, and Maria to stakeholders and policy makers: *"the time lag between observations and action is very very very long. Please hurry!!"*

Stefan Åström from IVL [presented](#) research from the EUA-BCA project on which specific sectors and solutions that would be most effective to reduce soot emissions in and around the Arctic region. Some of the measures are also important for improving local air quality and thereby human health, but some are more distinctly important as means to reduce Arctic Warming. For the countries in the Arctic region there are five emitting sectors that stands out. It is important to reduce emissions from small-scale wood combustion in stoves and fireplaces through better usage behaviour and equipment. It is also important to reduce the practice of flaring residual gas in oil and gas fields through better technologies or improved usage of residual gas. In addition, an enforcement of latest emission standards for non-road mobile sources and diesel vehicles. Finally, improved agricultural and forestry practices would enable a sharp reduction in open burning of agricultural residues and forest fires.

For the countries that are observers to the Arctic Council, such as India and China, the priority solutions are somewhat different. For these countries it is important to shift away from using solid fuels for cooking and heating and replace with gas-fuels or non-combustion solutions. A reduction of open burning is also important, but for these countries it is not only important to reduce open burning of agricultural residues, also open burning of municipal waste needs to stop. As for the Arctic countries, enforcement of emission standards for non-road mobile sources are important in the Arctic Council observer countries. But in these countries, there needs to be a special focus on curbing emissions from stationary diesel engines used to supply electricity.

All the mentioned solutions are characterised by their win-win-win for human health and the environment. If implemented, these solutions would reduce local and regional air pollution, the warming rate of Arctic Warming, and help achievement of several sustainable development goals.

Also related to climate change and air pollution is the relationship between exposure to air pollution and heat with respect to their joint effect on human health. Kristin Aunan from CICERO [presented](#) the Exhaustion project, in which such effects are studied. Although the project is just initiated, the results so far confirm previous research, but add detail, geographic resolution, and modelling sophistication to previous observations of the combined effects of air pollution and heat. The project also contributes with new insight regarding economic impacts by integrating high-resolution estimates of worker productivity losses in models accounting for economic dynamics. (computable general equilibrium models).

Air pollution effects on public health and the environment

Key messages

- Despite relatively clean air in the Nordic countries, air pollution still in 2015 caused 10 500 premature deaths annually in Denmark, Finland, and Sweden,
- Evidence of a lower boundary threshold for when air pollution cause health effects is yet to be identified,
- The environmental damages from ground-level ozone pollution appears to change nature rather than being solved,
- Nitrogen deposition is still too high over the Northern ecosystems.

The third session, split in two parts, went deeper into the state-of-art of how human health and the environment is affected by air pollution. The session on human health was designed as a [two-part](#) dialogue between Per-Everhard Schwarze from the Norwegian Institute of Public Health, Bertil Forsberg from Umeå University, Otto Hänninen from the National Institute for Health and Welfare, and Torben Sigsgaard from Aarhus University.

Air pollution is one of the environmental exposures with strongest epidemiological evidence on health risks and impacts. Even though the Nordic region has very clean air in global comparison, the estimated impacts are still substantial including thousands of annual deaths. According to best available estimates, in Denmark, Finland, and Sweden, the number of preterm deaths are around 4,000 (all pollutants), 1,800, and 4,700 in 2015 respectively.

There are large uncertainties, however, in the numerical estimates, and it is not clarified which pollutants are responsible of contributing to the burden. The epidemiological evidence emphasizes risks associated with fine particles (PM_{2.5}) and NO₂, but also ozone and PM₁₀ are consistently used in risk assessments. Because the air pollutant concentrations correlate, it is challenging to identify causal factors from covariates. For fine particles, uncertainty remains as to whether their toxicity is also affected by their chemical composition. Such composition varies between sources and seasons. A PM_{2.5} particle emitted from an industrial chimney is not constituted the same as a PM_{2.5} particle from road transport, but it remains to be clarified how different the toxicity is.

Another important uncertainty relates to how clean the air must be to be clean enough. International concentration-response models are commonly applying no-effect thresholds when estimating human health effects of air pollution. No-effect thresholds implies that the models used assumes that if the concentration of air pollutants in air is lower than a given value, the models assume no health effects. However, much recent research, including research from Nordic WelfAir and SCAC, fails to recognise any lower thresholds. In other words, the evidence for safe levels of air pollution remains elusive. Therefore, it remains of utmost importance to pursue epidemiological studies also in the Nordic region as is done e.g., in the Nordic WelfAir study.

Per Erik Karlsson and Filip Moldan from IVL [presented](#) new research on ozone and nitrogen damages on the Nordic environment. Ozone is formed from emissions of NO_x and volatile organic compounds, and when formed in low altitudes it acts as pollutant causing damages to vegetation, crops, forests, and materials. In the SCAC research program, the focus has been on studying ozone effects on forests in Sweden. The vegetation damage of a certain ozone concentration depends on humidity, sunlight, and whether it occurs when the vegetation is growing or not. SCAC monitoring has shown that the spring peak concentration of ozone occurs at earlier dates in the north parts of Sweden than the south parts. The trend is that this spring peak concentration is becoming higher and higher over time. An increase driven by climate variation, reduced emissions of NO_x , and increasing hemispheric background concentrations (imported ozone from non-European regions). In contrast, the summer ozone concentrations are decreasing over time. The studies on how ozone exposure affects stem growth on Norway spruce in southern Sweden utilized novel statistical methods, but the dataset used as input was too small to statistically demonstrate negative impacts of ozone on stem growth.

Nitrogen in its reactive form is an essential nutrient, but it has multiple and undisputable negative effects on ecosystems, human health, and climate change. Of focus for the Swedish research in the SCAC programme is to establish nutrient balances and establishing consistency between high-resolution monitoring and modelling of nitrogen. Data shows that in Sweden the nitrogen deposition decreased only by ca 30 % over the last 30+ years, whilst deposition of sulphur has decreased with more than 80%. Nitrogen deposition is still far too high!

Since reactive nitrogen drives numerous negative effects on human health, ecosystems and climate change, there is a need for a holistic view on management strategies. It is with a holistic view that the argument to reduce emissions of reactive nitrogen becomes powerful. The holistic view is however very complex, so experiments, models, and monitoring are needed to provide robust and accurate arguments for the policy purposes. One policy-adapted assessment tool is the construction of national nitrogen budgets, which gives a relatively complete overview of which fluxes/losses of reactive nitrogen that are the most important in a country or a region.

Sofie Hellsten from IVL focused in her [presentation](#) on emission from agricultural activities. The agricultural sector is the dominant source of ammonia emissions, and emissions are not reducing at the same pace as emissions of SO_2 , NO_x , and $\text{PM}_{2.5}$. Fortunately, there are many established measures available to reduce ammonia emissions, the current high emissions are rather a product of lack of successful policies. The easiest available options to reduce ammonia emissions from agriculture in the Nordic countries are to give livestock low-nitrogen feed, to cover up slurry and manure storages, and to increase the utilisation of low-ammonia manure spreading technologies.

Improving the knowledge needed for effective decisions

Key messages

- Nordic air pollution decision makers now have a consistent and high-resolution emission inventory for all Nordic countries,
- The importance of models requiring intensive computing power is increasing,
- The knowledge on decision processes given by qualitative methods is important for effective policies with maintained local relevance.

Air pollution policy is today supported by an extensive and integrated research infrastructure involving expertise and methods from numerous scientific disciplines. Ville-Vekko Paunu from SYKE [presented](#) the importance of regularly collecting an inventory of air pollutant emissions specified per pollutant, region, sector etc. Standardised inventories are fundamental for air pollution policy as means to check progress towards decided objectives. Good-quality inventories are also important for research: the higher the resolution of the inventory, the more useful it is for research purposes. In the Nordic-WelfAir project Nordic researchers have for the first time put together a 1 km² -resolution emission inventory for all Nordic countries.

At the other end it is also important to observe the state of the environment and where emitted air pollutants finally are deposited. Kjetil Törseth from the Norwegian Institute for Air Research [presented](#) the European monitoring of air pollution within the Air Convention. Although computer models have improved substantially the last decades, it is important to recognize that observations remain fundamental. Good quality observations are the basis for identification of potential health or environmental problems and for verification of progress of policies and efforts to reduce emissions. What the specifics are for 'quality' is much dependent of the purpose of the observation: it is not always necessary to make observations every second in every part of the world. In other words, the spatial and temporal resolution of the observation needs to be balanced against the problem addressed.

With information from detailed emission inventories and air quality monitoring stations it is possible for atmospheric physicist and chemists to develop atmospheric emission dispersion computer models. Lise Frohn from Aarhus University [presented](#) the basics of these types of models. Lise also presented some of the more prominent state-of-the-art emission dispersion models in the Nordic region, such as SILAM, MATCH, EMEP, and THOR. With the state of knowledge we have today, the most important improvements needed are to reduce uncertainty in emission estimates, increase understanding of physical and chemical atmospheric processes: in particular in relation to organic chemistry, increase geographical and temporal detail in emission inventories, and identifying the best proxies for air pollution exposure. For those not involved in the technical details of emission dispersion models, some

take home messages are more important than others. First, the level of complexity in the atmospheric transport of air pollutants is so high that advanced emission dispersion models and expert assessments are needed. Second, the accuracy of model results is linked to resolution of the model and the input data. Also, despite their complexity, the models are always evaluated by comparing their results with available air quality measurements.

Another important computer model in the toolbox is the integrated assessment model, which gives results more closely aligned with needs of policy makers. Mikael Skou Andersen from Aarhus University presented the features of such models by [exemplifying](#) with the Danish integrated assessment model EVA. Mikael presented how these models can calculate welfare costs of air pollution expressed in monetary terms by following the impact pathway approach. This approach includes modelling of emissions (or alternatively emission reductions), emission dispersion, environmental and human health exposure and effects, as well as monetary values of these effects. When following these steps, integrated assessment models can calculate the damages from air pollution and express these as €/ton pollutant emitted: a unit very useful for decision makers.

The third computer model concept of importance is an earth system model, often called 'climate models' in media. Such models are necessary to use if one wants to gain understanding of air pollutants effects on climate change. Annica Ekman from Stockholm University gave an [overview](#) of this type of models and how much they have improved over the last decades. In more detail she gave an overview of the NorESM model developed in Norway and Sweden. Thanks to models such as NorESM we now know that the largest regional impact of changes in north-hemispheric particle emissions always occurs in the Arctic, much due to transport of warm air up to the Arctic. We can also say that the longitudinal position of emissions does not matter much for emissions sources in the northern hemisphere and that the cooling effect of reducing 1 ton of black carbon is approximately corresponding to the warming effect of reducing 4 ton of sulphur emissions.

The final important method used to support air pollution policy is the wide range of methods collectively dubbed "qualitative methods". Particularly, Anne Jensen from Aarhus University [presented](#) how structured interviews can help the knowledge related to air pollution policy by allowing for an accounting of the complexity of the issues at stake, the heterogeneity of the persons affected, and how social and cultural aspects can affect acceptance for a policy, and thereby its effectiveness. In effect, qualitative methods such as interviews provide a deeper and richer knowledge of the complex interactions in society and context-dependent impacts of air pollution policies. Further, when done scientifically, the methods provide solid data on behaviours, processes, and interactions in society: data needed to understand the full effect of for example air pollution policies.

References

1. World Health Organization. Burden of disease from Ambient Air Pollution for 2012. 2014 Apr.
2. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu N, et al. The Lancet Commission on pollution and health. The Lancet. 2018;391(10119):462-512.
3. Thurston GD, Kipen H, Annesi-Maesano I, Balmes J, Brook RD, Cromar K, et al. A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework. European Respiratory Journal. 2017;49(1).
4. European Environment Agency. Air quality in Europe — 2020 report. 2020.
5. Amann M, Borken-Kleefeld J, Cofala J, Heyes C, Höglund-Isaksson L, Kieseewetter G, et al. Support to the development of the Second Clean Air Outlook. 2020.
6. Garmo ØA, Skjelkvåle BL, de Wit HA, Colombo L, Curtis C, Fölster J, et al. Trends in Surface Water Chemistry in Acidified Areas in Europe and North America from 1990 to 2008. Water, Air, & Soil Pollution. 2014;225(3).
7. Swedish Environmental Protection Agency. Mål i sikte - Analys och bedömning av de 16 miljö kvalitetsmålen i fördjupad utvärdering, Volym 1. 2015. Contract No.: Rapport 6662.
8. Norwegian Environment Agency. Acid Rain 2018 [Available from: <http://www.environment.no/Topics/Air-pollution/Acid-rain/>].
9. Sutton MA, Grinsven HV, Billen G, Bleeker A, Bouwman AF, Bull K, et al. Summary for policy makers. In: Sutton MA, Grinsven HV, Billen G, Bleeker A, Bouwman AF, Bull K, et al., editors. The European Nitrogen Assessment - Sources, effects and policy perspectives: Cambridge University Press; 2011.
10. Ebi KL, McGregor G. Climate Change, Tropospheric Ozone and Particulate Matter, and Health Impacts. Environmental Health Perspectives. 2008;116(11):1449-55.
11. Van Dingenen R, Dentener FJ, Raes F, Krol MC, Emberson L, Cofala J. The global impact of ozone on agricultural crop yields under current and future air quality legislation. Atmospheric Environment. 2009;43(3):pp 604-18.
12. European Environment Agency. Healthy environment, healthy lives: how the environment influences health and well-being in Europe. 2019.

13. Sand M, Berntsen TK, Ekman AML, Hansson H-C, Lewinschal A. Surface temperature response to regional black carbon emissions: do location and magnitude matter? *Atmospheric Chemistry and Physics*. 2020;20(5):3079-89.
14. Ekman A, Langner J, Hansson H-C, Gruzjeva O, Forsberg B, Andersson C, et al. Swedish Clean Air and Climate Research Programme – SCAC, Final report second phase. The Swedish Environmental Protection Agency; 2020.
15. Krishnan S, Ekman AML, Hansson HC, Riipinen I, Lewinschal A, Wilcox LJ, et al. The Roles of the Atmosphere and Ocean in Driving Arctic Warming Due to European Aerosol Reductions. *Geophysical Research Letters*. 2020;47(7).
16. Segersson D, Johansson C, Forsberg B. Near-Source Risk Functions for Particulate Matter Are Critical When Assessing the Health Benefits of Local Abatement Strategies. *International Journal of Environmental Research and Public Health*. 2021;18(13).
17. Karlsson PE, Klingberg J, Engardt M, Andersson C, Langner J, Karlsson GP, et al. Past, present and future concentrations of ground-level ozone and potential impacts on ecosystems and human health in northern Europe. *Sci Total Environ*. 2017;576:22-35.
18. Paunu V-V, et al. Spatial distribution of residential wood combustion emissions in the Nordic countries: How well national inventories represent local emissions? Submitted.
19. Kukkonen J, López-Aparicio S, Segersson D, Geels C, Kangas L, Kauhaniemi M, et al. The influence of residential wood combustion on the concentrations of PM_{2.5} in four Nordic cities. *Atmospheric Chemistry and Physics*. 2020;20(7):4333-65.
20. Lehtomäki H, Geels C, Brandt J, Rao S, Yaramenka K, Åström S, et al. Deaths Attributable to Air Pollution in Nordic Countries: Disparities in the Estimates. *Atmosphere*. 2020;11(5):467-82.
21. Olsson D, Forsberg B, Braback L, Geels C, Brandt J, Christensen JH, et al. Early childhood exposure to ambient air pollution is associated with increased risk of paediatric asthma: An administrative cohort study from Stockholm, Sweden. *Environ Int*. 2021;155:106667.
22. Raaschou-Nielsen O, Thorsteinson E, Antonsen S, Holst GJ, Sigsgaard T, Geels C, et al. Long-term exposure to air pollution and mortality in the Danish population a nationwide study. *EClinicalMedicine*. 2020;28:100605.

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